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# Direct Visual Approximation of Arch Length Discrepancy and Cephalometric Measurements

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DIRECT VISUAL APPROXIMATION OF ARCH LENGTH DISCREPANCY  
AND CEPHALOMETRIC MEASUREMENTS

By  
Bradley Wurm, DDS

A Thesis Submitted to the Faculty of the Graduate School, Marquette University,  
in Partial Fulfillment of the Requirements for  
the Degree of Masters of Science

Milwaukee, Wisconsin  
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ABSTRACT  
DIRECT VISUAL APPROXIMATION OF ARCH LENGTH DISCREPANCY  
AND CEPHALOMETRIC MEASUREMENTS

Bradley J. Wurm, DDS

Marquette University, 2017

**Introduction:** Arch length discrepancy and cephalometric analysis are critical components of orthodontic treatment planning. Both have direct effects on the decision to extract teeth or not and treatment mechanics as well. Visual approximation is the most common method used to analyze arch length discrepancy among practitioners. Current trends show a decrease in the amount of orthodontists completing a cephalometric analysis. Previous studies have shown a tendency for orthodontists to overestimate the degree of crowding when visually approximating on dental casts. No previous study has assessed the ability to visually approximate cephalometric angle measurements. The purpose of this survey was to determine the accuracy of orthodontists to visually approximate cephalometric angular measurements and arch length discrepancy using occlusal clinical photos

**Methods and Materials:** Fifty-four orthodontic residents and clinicians were recruited in this project and completed a survey that included a section on demographics, 3 upper and lower occlusal photos of 3 orthodontic cases, and 3 cases of traced cephalograms.

**Results:** An assessment of the effects of demographics on crowding and cephalometric assessment were done with one-way ANOVA and Chi-Square tests, respectively. No clear associations between any demographics and results were found. Results showed a trend to overestimate crowding. Cephalometric responses did not have a high level of accuracy.

**Conclusions:** On average, orthodontists overestimated all arch length discrepancy measurements. Overall, orthodontists were not accurate at approximating cephalometric measurements, with a total of 50% choosing the correct measurement range.

## **ACKNOWLEDGMENTS**

Bradley J. Wurm, DDS

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## CHAPTER I

### INTRODUCTION

Orthodontics is the field of aligning teeth for proper occlusion, function and esthetics. In order to do so, the practitioner must decide on the proper steps to take to achieve this goal. Before any of this can take place, a proper diagnosis must be made that includes all components of each individual patient. This diagnosis begins with a clinical exam and is confirmed with the review of records, generally including clinical photos and/or models and radiographs.

A proper diagnosis addresses not only the dental occlusion and alignment, but also the skeletal and facial features. In fact, modern orthodontics are now considered facially driven, with a primary focus on how treatment will affect facial features rather than simply achieving a good occlusal relationship (1). Within each of these three components, there are three dimensions to diagnose. These include the vertical, anteroposterior and transverse direction. It is the responsibility of the orthodontist to recognize the normal and abnormal findings in all dimensions.

While every component of the records and diagnosis have significance, this study will focus on two in particular: the space analysis and the radiographic/skeletal component. While it is far from the first time these will be the focus of research, this study will target new information that will aim to guide clinical practices.

Orthodontists are always searching for new ways to increase efficiency while maintaining quality. This study will examine if visual approximation, an efficient method, can maintain as high of a level of accuracy as other available methods when determining arch length discrepancy and lateral cephalometric measurements. The objective will be to determine if visual approximation is an appropriate clinical diagnosis tool to be implemented into daily practice as a replacement for conventional measuring methods.



## CHAPTER II

### BACKGROUND AND SIGNIFICANCE

#### Arch Length Discrepancy

Arch Length Discrepancy is the difference between the space available, generally determined by the bony dental alveolus, and the space required or the sum of all mesiodistal tooth widths. If the space available is larger than the sum of the widths, this is known as spacing. If the space available is less than the sum of widths, this is known as crowding. This arch discrepancy appears to be a result of inadequate arch dimensions rather than excess tooth size (2). Crowding often results in overlapping and rotation of the teeth (2). Measuring this by hand can be a tedious process and introduces the possibility of human error. Because of this, orthodontists continue to look for a more efficient and accurate way of estimating the arch length discrepancy. Many orthodontists learn various methods of space analysis during residency programs. One example is the Royal London Space Analysis, which has been shown to have high inter- and intra-examiner reliability (3), although little research on its accuracy is available. Another example uses intramolar width to determine space available. An arch template is selected based on the width and then used to find the space available (4). This method uses an arch template based on patient averages and assumes that all patients should have the same arch shape; however, this has been shown not to be an appropriate assumption (1).

Previous studies have investigated the accuracy of space analysis using computers to measure photocopies of models (5,6,7). Yen was the first to assess this method with the rationale that measurement of a 3-dimensional object has a high potential for error and a 2-dimensional transfer would be easier and produce the same results (5). Another study shortly after

countered Yen's findings, showing that photocopies were unreliable, but nevertheless agreeing that photocopies provide advantages for clinical practices both during and after treatment (6). A third study was done that found that the computer measuring system was reliable, but the inability to determine convexities and inclinations from a 2-dimensional photo led to less reliable results compared to manual measurement (7).

More recent studies have focused on how accurate orthodontists are at visually approximating arch length discrepancy/crowding (8,9,10). These studies have shown that orthodontists using visual approximation have a tendency to overestimate the amount of crowding. Johal showed that reflex microscopes produce a consistent result whereas visual approximation overestimates and brass wire underestimates comparatively (8). Interestingly, when given the option of tools to use to measure crowding, all orthodontists elected to forego these tools and estimate based on visual approximation only (9).

Although previous studies showed that a 2-dimensional photocopy was not a reliable source to assess arch length discrepancy, a recent study showed that clinical photos were reliable when compared to dental cast measurements (11). The only exception was with the mesiodistal width of upper first molars. For our study, the molar width was not used when calculating crowding. No previous studies have assessed the use of clinical photos for visual approximation.

### **Lateral cephalograms**

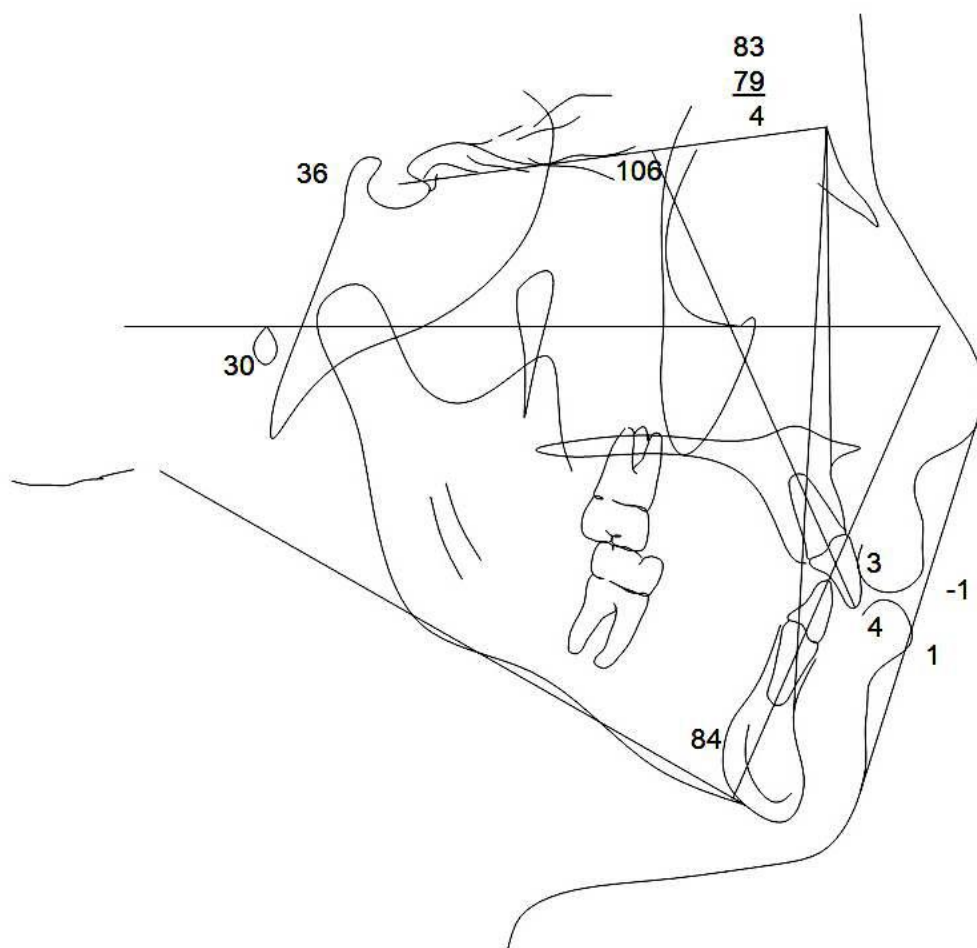
A lateral cephalogram is a radiograph that is taken from the side of a patient's head to obtain a sagittal view of the patient's skeletal structure. The cephalogram was brought to the field of orthodontics by Dr. Broadbent in the 1930s and has since been a standard tool for treatment planning. The cephalogram is 1 of 2 common radiographs taken by orthodontists with

the other being a panoramic radiograph. While occasionally pathology is noted on the cephalogram, it is not taken for that purpose (1). The panoramic is more suitable as a pathologic screening tool. Instead, the cephalogram is used to analyze growth patterns, vertical and anteroposterior skeletal proportions as well as tooth positions. Serial cephalograms taken at different time periods and superimposed on each other are used to analyze patient growth and development or effects and results from treatment.

### **Cephalometrics**

Cephalometrics, as the name implies, is the analysis of measurements from a patient's cephalogram. This is done by the identification of various landmarks that are then used to find linear and angular measurements. These are then compared to a norm to analyze the patient's skeletal and tooth structural positions. While originally used for research on growth patterns, cephalometrics has become a tool for diagnosing malocclusion as well as any underlying skeletal discrepancies that may be causing this malocclusion (1). The orthodontist must be able to recognize if a malocclusion is a result of dental malalignment or if it is due to jaw position. The same malocclusion may be treated differently depending on which is the cause. Clinical observation of the face can provide some of this information, but cephalograms, more importantly cephalometric analysis, allows greater precision in this diagnosis (1). Initially, cephalometric analysis was a lengthy process done by hand tracing and manual measuring, but this time requirement has been drastically reduced as manual tracing has progressively been replaced by digital tracing (1). Programs can give measurements and the deviation from the norm once the points have been identified. Some programs will even identify the landmarks, requiring the orthodontist only to confirm their location. Many analyses exist, each with its own list of measurements and norms. The ABO has its own analysis that is used for evaluation of

cases. For this study, four specific measurements were focused on. *Fig 1* shows an example of the ABO tracing and analysis. A description of the measurements used in this study will be discussed.



**Figure 1. American Board of Orthodontics Cephalometric Analysis.** An example of the complete analysis used for ABO case review. Four of these measurements were used in this study.

## **ANB**

One of the most commonly used measurements, ANB is the angular measurement of point A to Nasion to Point B. It focuses on the anteroposterior relationship of the maxilla to the mandible. Point A is the innermost point on the contour of the premaxilla between anterior nasal spine and the incisor tooth (1), Point B is the innermost point on the mandible between the incisor and chin (1). Nasion is the junction point between the nasal and frontal bone (1). While this measurement does have short comings (12), it is used in many analyses and is used by the ABO as its measurement of maxillomandibular anteroposterior relation.

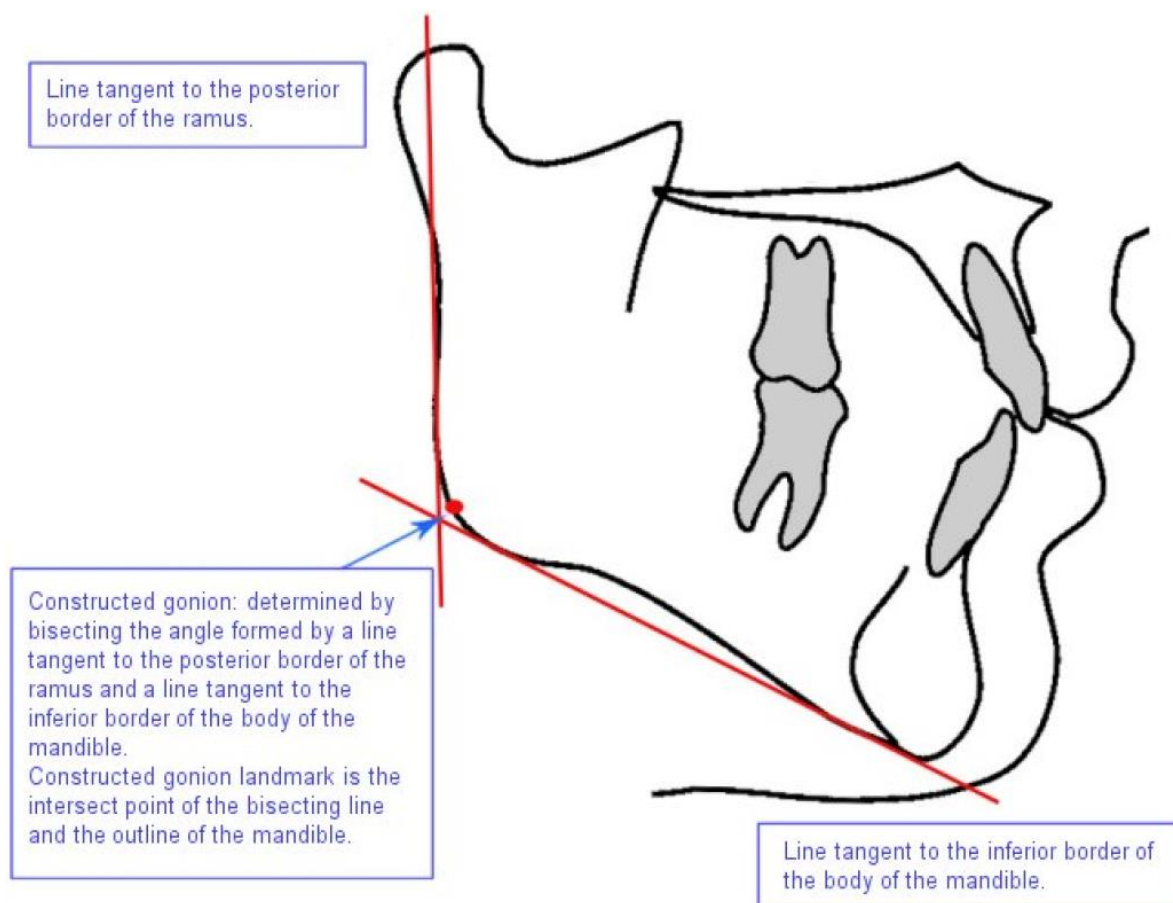
## **U1-SN**

This measurement evaluates the inclination of the maxillary or upper central incisor in relation to the cranial base. U1 is a line that passes from the incisal tip of the upper central incisor through the root apex. SN is a line that passes from sella to nasion. Sella is the midpoint of the cavity of sella turcica (1). Nasion is as previously discussed. This line represents the anterior cranial base and is a commonly used reference plane due to its stability, practicality and ease of locating (13).

## **L1-MP**

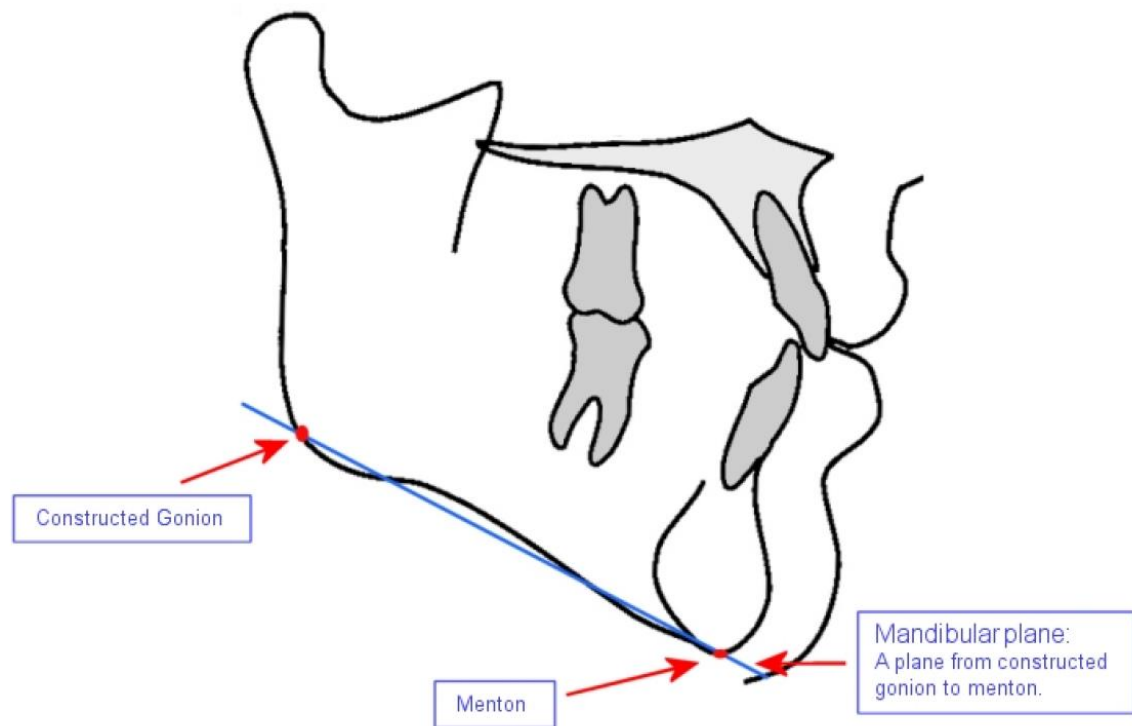
This measurement evaluates the inclination of the mandibular or lower central incisor in relation to the mandibular plane (MP). L1 is a line that passes from the incisal tip of the lower central incisor through the root apex. MP has slight variations in construction depending on the analysis used, but is always meant to represent the plane of the lower border of the mandible. In the case of the ABO analysis, it is a line that passes from menton (Me) to constructed gonion

(Go). Menton is the most inferior point on the mandibular symphysis (1). Constructed gonion is not a specific landmark located on the radiograph, but is constructed, as the name implies, by using other landmarks. To do so, a line is drawn tangent to the inferior border of the mandible from menton to gonion. Not to be confused with *constructed* gonion, gonion is the most inferior point on the curvature of the angle of the mandible. Another line is drawn tangent to the ramus of the mandible. This line passes from ramus point, the most posterior point on the posterior border of the ramus, to articulare, the point where the posterior border of the condyle/ramus intersects with the shadow of the zygomatic arch (1). A line is drawn bisecting the angle formed by these two lines. Constructed gonion is the intersecting point between this bisecting line and the outline of the mandible. *Fig 2 & 3* demonstrates the location of constructed gonion and mandibular plane, respectively.



**Figure 2. Constructed Gonion.** The point is not an identifiable landmark, but rather is created using other landmarks and angles.





**Figure 3. Mandibular Plane.** The American Board of Orthodontics uses constructed gonion to form the mandibular plane.

## **MP-FH**

MP-FH, also referred to as Frankfort-Mandibular Plane Angle (FMA), is an angle that evaluates the directional growth of the mandibular plane, often referred to as the vertical growth pattern. MP is as previously discussed. Frankfort Horizontal (FH) is a line that passes from Orbitale (Or) to Porion (Po) and is used as a horizontal reference plane, similar to SN. Porion is the highest point on the external auditory canal (1). Orbitale is the lowest point on the inferior border of the orbit (1). The objective of Frankfort Horizontal is to identify a true horizontal plane. However, the shortcoming of this plane is that identification of both Porion and Orbitale are difficult and can lead to error (1).

## **Treatment planning**

Treatment planning is the design of a strategy that addresses the diagnostic findings and achieves all treatment goals as best as possible. As defined by Proffit, “the objective in treatment planning is to design a strategy that a wise and prudent clinician, using his or her best judgment, would employ to address the problems while maximizing benefit to the patient and minimizing cost and risk” (1). As mentioned, space analysis is a key component in the diagnosis and treatment planning. Oftentimes, some amount of arch length deficiency exists and an orthodontist must elect how to create more space. Some options include transverse or anteroposterior expansion of the arch, interproximal enamel reduction, or the extraction of teeth.

Research has shown that the degree of dependability on lateral cephalograms for treatment planning may depend on educational background as well as level of experience (14). As practitioners have been out of school for longer, the tendency is to depend less on

cephalometrics. Silling et. al found that some, but not all, cases had complete agreement on treatment whether or not a lateral cephalogram was given (14). Deveroux et. al found that when given a lateral cephalogram, the largest change in treatment is the extraction pattern (42.9%); however, 19.7% of practitioners changed their decision to extract or not, and 24% decided to reinforce anchorage (15). In 1986, Gottlieb reported that 97.3% of orthodontists routinely take lateral cephalograms (16). More recently, it was reported that 60% of orthodontists take a pre-treatment lateral cephalometric radiograph on every patient, while another 34% take a cephalogram on 66-99% of cases (17). Possible explanations for this decrease in obtaining lateral cephalograms includes the gaining popularity of cone beam CT scanners as well as the increasing awareness and fear of the effects of radiation exposure. Also as discussed earlier, it appears that perhaps this historically routine use of cephalograms in diagnosis may not be as critical as previously thought (14). Only 39% of orthodontists report doing a formal analysis on every cephalogram (19% do an analysis on 66-99% of cases) (17). So out of this 42% that are not performing an analysis regularly, how accurate are the orthodontists at reading a cephalogram visually only? Because if visually estimating cephalometrics is not accurate, then the question becomes should a patient be exposed to the extra radiation at all if an analysis is not going to be performed. This will be discussed according to the results of this study.

### **Extraction vs non-extraction**

Extraction of teeth is a highly debated topic in the field of orthodontics. The decision to remove teeth is done for facial/dental esthetics, stability of results, and proper occlusion (1). However, some clinicians feel the disadvantages of removing dental units outweigh the advantages. This argument has existed from the very beginning of modern orthodontics. Edward

Angle, often considered the Father of Modern Orthodontics, believed that “there shall be a full complement of teeth, and that each tooth shall be made to occupy its normal position.” (18) On the other hand, during the same period of time Calvin Case argued that extractions often had a practical use (18). The argument has continued ever since with the rate of extraction fluctuating along the way. In 1950, 10% of cases were extraction; in 1960, 50% were extraction; Finally, by 1980, the rate began to stabilize at 30% (19). Crowding, specifically lower crowding has been shown to be the most important variable in the decision to extract (19). The severity of crowding, in and of itself, can alter the plan of treatment (1). A general rule is if the arch length discrepancy is under 4mm, no extractions are necessary. If it is 10mm or more, extractions are necessary; anything in between is case specific and based on the orthodontists judgment (1). These borderline cases are especially important for the orthodontist to have an accurate knowledge of the amount of crowding present. In borderline cases, practitioners have been shown to change their decision to extract or not when learning that the true amount of crowding differs from their visual approximation (10). In non-extraction treatment, the amount of crowding present needs to be compensated for by increasing the arch length either with transverse expansion, posterior distalization, or advancement of the anterior (20). This often leads to expansion of the mandibular canine width (20,21,22). This specifically has been well-documented to lead to issues with stability (23,24,25,26). This instability is a major argument of those in favor of selective extractions.

Some changes after treatment are inevitable (27,28), but the goal is to reduce this to a minimum. Non-extraction treatment has been shown to lead to greater relapse of maxillary anterior crowding (29). Extraction treatment is not without its own instability. Overbite relapse is more common in patients treated with extractions (29).

One other option for cases with moderate crowding that are borderline for requiring extraction is interproximal reduction. This involves the removal of small amounts of enamel from the interproximal surfaces of teeth, often the mandibular anterior, to create some extra space. As it turns out, the choice between these two options may not have as much of a change on the treatment result as initially thought. It has been shown that with proper treatment, class I cases with moderate crowding treated with extractions do not narrow the arch while non-extraction with interproximal reduction does not widen the intercanine width (30). In the end, they both resulted in similar intercanine and molar width (30).

Similar to the attempts to create a quick crowding estimation, there have also been attempts to mathematically calculate whether a case requires extractions or not (31,19). One equation produced a 90% agreement rate when retrospectively compared with the treatment that was performed (31). However, as mentioned before, different orthodontists have different viewpoints on extractions. Therefore, this reported accuracy rate only applies to the limited group of practitioners involved in the study. If such a mathematical model were to be used, it would need to be calibrated to each individual orthodontist's preferences.

The fact is there will never be a complete agreement amongst practitioners on when teeth should or should not be extracted. However, it is important to have an accurate diagnosis when making this decision. Incorrect measurements can lead to a change in treatment mechanics at the minimum, and may even alter the decision to extract or not. Therefore, this study will determine the accuracy of making these measurements based on visual approximation and determine if this is an acceptable clinical practice.

## **Chapter III**

### **MATERIALS AND METHODS**

#### **Materials**

Dolphin Imaging software was used for uploading digital photos and lateral cephalograms. Dolphin Imaging and its ABO 2012 presetting was used for cephalometric analysis. Impressions were taken with alginate. Impressions were poured up in plaster and models were scanned with MotionView Ortho Insight 3D® scanner. Ortho Insight 3D® software was used to obtain model measurements.

#### **Subjects**

Fifty-four subjects participated in this survey. Subjects were comprised of orthodontists and orthodontic residents. This included faculty and residents of Marquette University Orthodontics Clinic as well as residents and orthodontists from the Stomatological Hospital of Jiangsu Province Department of Orthodontics in Nanjing, China. Age and expertise of subjects ranged from residents in their mid 20s to practicing orthodontists with over 50 years of experience and in their 80s. Faculty members had a variety of different residency training backgrounds. All subjects were asked by the primary investigator or faculty supervisor to complete the survey. All subjects completed the survey voluntarily and had no requirement or incentive to do so.

## Survey

A survey with 3 sections was given to participants. Instructions were printed on the survey and any questions as to the nature of the survey were addressed, but no questions were answered that may influence the subject's measurements. The initial portion of the survey contained 5 questions on participant descriptive information, including gender, age, level of expertise as well as their routine method of measuring crowding and frequency of tracing cephs.

The next section of the survey contained 3 maxillary and 3 mandibular clinical occlusal photos in full color. Participants were instructed to estimate the amount of crowding on each case, rounding to the nearest 10<sup>th</sup> of a millimeter. No tools for measuring were allowed. Instructions stated to use the current arch form and not consider curve of Spee or Wilson or inclination of incisors. This instruction was given to standardize the measurement between participants. It was recognized that this is not necessarily the method used by all practitioners and some cases may indeed warrant arch expansion, etc. However, the objective was to prevent any inconsistency that would result from different opinions on options such as expanding the current arch form or changing incisor proclination and thus reduce the crowding estimate.

The final section of the survey consisted of three lateral cephalograms. Participants were asked to select from a range of measurements for ANB, U1-SN, L1-MP, and MP to FH. The ABO norm was given for each measurement. Five equal ranges were provided for each measurement. These ranges were identical for each of the three cases. Participants were instructed to select which range they estimated the true measurement to fall into. Again, no tools for measuring were allowed.

### Calculating true measurements

Determination of the true measurements were done with computer analysis. Alginate impressions were previously taken at an initial records appointment. Plaster models were fabricated and then scanned with MotionView Ortho Insight 3D® scanner. Ortho Insight 3D® software was used to determine crowding. Previous studies have shown that digital models and plaster models result in similar crowding measurements, the only exception being a slightly higher, although clinically insignificant, amount of crowding in the maxilla (32). All tooth landmarks and widths were initially placed by the software program and then manually checked and adjusted as necessary. A catenary arch form from mesial of 1<sup>st</sup> molar to 1<sup>st</sup> molar was laid over the current arch form. The Catenary Crowding measurement calculated was used as the true measurement for each case. Ortho Insight 3D provides both a Catenary as well as Overlapping measurement. The Catenary measurement was used as opposed to the Overlap measurement because this method better resembled how participants were instructed to calculate their own measurements and it has been reported to be the more commonly used technique (8). At a later date, all landmarks were reset. All steps were repeated to find catenary crowding for a second time. The average of these two measurements was used as the true crowding measurement.

Lateral cephalometric tracings were done using Dolphin Imaging software. Santoro et al showed that digital and hand tracing are both reliable methods of tracing cephs (33). The ABO 2012 landmark/analysis preset was used for all measurements. Landmarks were manually located. Landmarks were confirmed at a later date, at which point no adjustments were made.



**Statistical analysis**

Statistical analysis was performed using one-way ANOVA followed by Tukey B post-hoc comparison for crowding measurements. Chi-Square tests were used for cephalometric comparisons. P-value  $<0.05$  was considered to indicate significant difference. All statistical analyses were performed by Ms. Kate Sherman, statistician of Marquette University.

## CHAPTER IV

### RESULTS

#### Comparison based on descriptive information

First, we set out to determine if there is a relationship between the descriptive information provided by participants and their results. These included a comparison based on age, gender, nationality, level of expertise, and frequency of cephalometric tracing. No significant difference was found based on gender for any measurement. When comparing based on expertise, the only difference found was in case 1 upper crowding. It was found that residents had a significantly lower error than those with 1-5 years of practice. Those with 5+ years of practice were not significantly different from either group. Only one measurement was found to have a significant difference based on age. For case 1 L1-MP, it was found that responses were more likely to be correct as age increased. The differences found based on frequency of cephalometric measurement and nationality can be found below in **Tables 1 and 2**, respectively.

Due to low cell counts, the p-value was often artificially low and thus it was difficult to determine what was truly significant versus what was artifact. This should be considered during interpretation of these results.

**Table 3** shows the results of crowding approximation based on what method of space analysis the practitioner uses in practice. Apart from finding the descriptive statistics, no analysis was done, but a comparison of the means is shown.

**Table 1. Differences based on frequency of cephalometric tracing.** Differences listed had significance of  $p < 0.05$  unless otherwise noted.

	<b>Almost every patient</b>	<b>When unsure of treatment</b>	<b>Rarely/never</b>
<b>ANB1</b>	More likely to be correct		
ANB2			
ANB3			
U1-SN1			
<b>U1-SN2</b>	More likely to be correct or overestimate*		
U1-SN3			
L1-MP1			
L1-MP2			
<b>L1-MP3</b>	More likely to be correct or overestimate		
FMA1			
FMA2			
FMA3			

\* denotes borderline significance ( $p=0.063$ )

**Table 2. Differences based on Nationality.** Groups were significantly more likely to have the results listed ( $p < 0.05$ ).

	<b>American</b>	<b>Chinese</b>
<b>Upper1</b>	Smaller error size	
<b>Upper2</b>	Overestimate	Underestimate, smaller error size
Upper3		
Lower1		
Lower2		
<b>Lower3</b>		Smaller error size
ANB1		
ANB2		
ANB3		
<b>U1-SN1</b>	Underestimate	Correct
U1-SN2		
U1-SN3		
<b>L1-MP1</b>	Underestimate	Overestimate
<b>L1-MP2</b>	Correct	
L1-MP3		
FMA1		
FMA2		
FMA3		

**Table 3. Differences based on method of space analysis used in practice.** Measurements listed for each method are the mean of all responses.

	Upper 1	Upper 2	Upper 3	Lower 1	Lower 2	Lower 3
True Measurement	0.8	6.1	7.2	2.4	5.6	7.2
Visual Approximation	1.40	6.56	7.99	2.87	6.06	8.00
Manual Measurement	2.02	6.44	8.46	2.20	5.66	7.22
Computer Estimate	1.05	6.75	7.65	2.45	6.25	7.85
Visual Approximation & Manual Measurement*	1.00	5.83	7.17	1.83	5.17	6.83

\* 3 total responses

### Overall trends

Next, we examined the entire group of participants to determine the overall results found. As seen in **Table 4**, the mean for each case of crowding was an overestimation with a range of 0.18-1.00mm. For the cephalometric responses, there was no clear pattern of over or underestimation amongst the measurements. However, **Table 5** shows the percent of correct responses for each measurement. Overall, approximately 50% of all responses across all measurements were correct.

**Table 4. Descriptive statistics of crowding responses.**

	<b>Upper1</b>	<b>Upper2</b>	<b>Upper3</b>	<b>Lower1</b>	<b>Lower2</b>	<b>Lower3</b>
<b>True Measurement</b>	0.8	6.1	7.2	2.4	5.6	7.2
<b>Mean</b>	1.80	6.51	8.17	2.58	5.95	7.74
<b>Average Overestimation</b>	1.00	0.41	0.97	0.18	0.35	0.54
<b>Standard Deviation</b>	0.98	1.83	1.63	0.98	1.44	1.36
<b>Range</b>	5.50	9.00	8.50	5.50	6.00	6.00
<b>Minimum</b>	-1.50*	3.00	5.00	0.50	3.00	5.00
<b>Maximum</b>	4.00	12.00	13.50	6.00	9.00	11.00

\* A negative number denotes a response indicating spacing available in the arch





## CHAPTER V

### DISCUSSION

From the statistical analyses, it is difficult to find patterns amongst the descriptive groups. For example, for L1-MP1, Americans tended to underestimate compared to Chinese, but for L1-MP2, they tended to be more correct. For L1-MP3, there was no tendency for either. When looking at the three cases, there is no clear clinical explanation for this variance. When considering the frequency of tracing in practice, it would appear as if those who trace cephalograms on almost every patient tend to be more accurate. However, as mentioned in the previous section, it is difficult to explain the p-value found for some results. Due to the low number of responses, not all categories had a response for all options. For one example, when analyzing ANB1, there were no underestimating responses for the “rarely/never” or “when unsure of tx” groups. In general, most subjects were in the “almost every pt” group so there are minimal responses in any other table cell. Because of this, it is difficult to interpret if these statistical results hold true, or if the result is due to the lack of total responses leading to low numbers in other cells. In conclusion, more responses are needed before any inferences can be made. Ideally, these results would be from a larger variety of locations to provide a greater variation in routine clinical practices.

It has been previously documented that orthodontists tend to overestimate the amount of crowding present (8,9,10). This study is in agreement with these previous studies. However, it broadens the research to include clinical photos as well. Orthodontists have a tendency to overestimate crowding when visually approximating from clinical occlusal photos. This study did not investigate whether an actual knowledge of crowding would affect the treatment plan of the orthodontist. This is because the decision to extract or not is based on many factors including not only crowding, but also flare of the front teeth, depth of the curve of Spee, etc. It

was decided that this may lead some to ignore the instructions given and bring their clinical opinions into their treatment decisions as well as their crowding approximations. While there was a large range of responses, the overall mean overestimation was 1 mm or less for each case. This is a smaller amount than some of the previous studies and may or may not be clinically relevant.

No previous study has examined how accurate practitioners are at visually approximating lateral cephalometric measurements. This study demonstrates that, similar to the approximation of crowding, practitioners are not accurate. While some cases showed more accurate results than others, each measurement showed an overall accuracy rate of approximately 50%. Unlike the space analysis, there is no clear pattern of over or underestimation. Although no clear explanation for this exists, there are some differences between the two that may have some influence. One difference is the nature of the measurements. The fact that cephalometric measurements are angular while crowding is a linear measurement may have some influence. Also, having subjects choose from a range of measurements rather than choosing a specific measurement may camouflage part of the error in their approximation. For example, whether the subject believes the measurement to be on the low or high end of the range, their response would still appear the same. Furthermore, even if the subject indicated a correct response, they could, in theory, be over or underestimating the true measurement. By using a range for the answer, there is an error built into the research design that may hide a pattern of response. However, the study was designed to resemble clinical practices. Cephalometric analyses have norms with a standard deviation. Clinicians are not necessarily as concerned with the precise measurement as is the case with crowding. Instead, they are concerned with how much the patient deviates from the norm. This study

shows that practitioners do not appear to be accurate at visually approximating how much a measurement deviates from the norm.

With only a single difference found, it appears that there is no overall effect of expertise level on the ability to visually approximate. Despite what one might expect, the ability to estimate measurements does not appear to improve throughout a career. One might also expect that the clinicians who regularly use visual approximation would have better results. Although it was not statistically analyzed, the method of space analysis used in practice did not appear to affect the result. A possible explanation for this is that clinicians who use visual approximation in practice never see if their estimates are correct or not. Therefore, they continue in their habit of overestimating without ever recognizing their mistake. Interestingly, the 3 participants who indicated that they regularly use visual approximation AND manual measurement had the closest results overall, commonly even slightly underestimating the true crowding. This sample size is far too small to draw any inferences from. However, future research could investigate whether using manual or computer measurements to assess visual approximations may increase accuracy long term. This may be an appropriate combination to implement during residency and training in order to increase accuracy of visually approximating.

In Normando's study on accuracy of intraoral photos, the photos were taken using cheek retractors with a ruler on them (11). While in their study, the purpose of the ruler was to aid in computer analysis, this is also a possible addition for those who use visual approximation in order to have a size reference. Otherwise, clinicians must rely on measurements made clinically or use average tooth widths for a baseline.

For this study, subjects were instructed not to consider curve of Spee since it is not clearly visible from an occlusal photo only. Unfortunately, this cannot be controlled in the computer analysis program. All teeth landmarks were placed using a 3-dimensional view of the

teeth rather than only an occlusal view. When the computer aligns the teeth, it eliminates all vertical discrepancies as well. Therefore, curve of Spee was corrected in the computer's calculation of crowding. Some of the previous studies that used models required subjects to consider curve of Spee in their calculation of crowding (9). Future studies could include lateral views that would allow subjects to add this to their estimates. Interestingly, if subjects were to consider the curve of Spee, this would only increase their crowding estimates, which would make the results more comparable to previous studies. Consequently, this study may be understating the amount that practitioners are overestimating.

### **Implications of study**

Practitioners should recognize that visually approximating crowding can lead to an overestimation of the true crowding. For some cases, this may make no difference in treatment planning; but for borderline extraction cases, this may lead to the orthodontist choosing to extract teeth when they may not need to. Orthodontists must be aware of this and either improve the accuracy of their approximation by checking their estimates to true measurements, or in cases that they are uncertain of whether or not to extract, they should opt to calculate the true crowding rather than rely on an inaccurate approximation.

This study shows that orthodontists are not good at approximating cephalometric angle measurements. Accordingly, for accurate diagnosis, orthodontists should trace and measure cephalometrics either by hands or program. There is already some debate if cephalograms affect treatment planning even when a proper analysis is performed. For those who routinely take lateral cephalograms on patients but do not complete a cephalometric analysis, they may still use for the radiograph for valuable information such as evaluating bone shape or size, root resorption, CVMS, etc. However, if they are not using the cephalogram for any of this

information, they should reevaluate if there is justification for the radiation they are exposing their patients to.

## Chapter VI

### SUMMARY AND CONCLUSIONS

Practicing orthodontists and residents were surveyed on their ability to visually approximate arch length discrepancy and cephalometric measurements. Participants were also asked about their demographics and routine practices.

On average, all visual approximations of crowding were larger than the true measurements. Without a larger sampling, no clear associations can be made between accuracy and gender, age, nationality, level of expertise, or routine method of arch length discrepancy measurement.

Overall, orthodontists are not accurate at visually approximating cephalometric angular measurements. There is no pattern of over or underestimation. Without a larger sampling, no clear association can be made between accuracy and gender, age, nationality, level of expertise, or frequency of performing cephalometric analysis.

#### **Conclusions:**

1. When visually approximating arch length discrepancy in occlusal photos, orthodontists have a tendency to overestimate the amount of crowding present.
2. Orthodontists are not accurate at visually approximating lateral cephalometric measurements.
3. The daily method of space analysis used by a practitioner does not appear to have an effect on how accurate they are when visually approximating arch length discrepancy.

4. There is no clear pattern between gender, age, nationality, or level of expertise and the ability to visually approximate arch length discrepancy or lateral cephalometric angular measurements.
5. Orthodontists should use a different method of space analysis other than visual approximation if they believe a case to be borderline in treatment mechanics or the decision to extract.
6. Orthodontists must determine their justification for taking a cephalogram on a patient if a proper cephalometric analysis is not to be performed.

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## Appendix A

### Direct Visual Approximation of Arch Length Discrepancy and Cephalometric Measurements

The purpose of this study is to compare subjects' visual estimation of crowding and lateral cephalometric measurements with the true measurements computed using Motion View and Dolphin Imaging software. Analysis will also determine if level of experience influences the accuracy of responses. Participation in this survey is voluntary with no known risks associated. Results will be anonymous and subjects will not be identified in any reporting of results.

☐ By checking this box, I am indicating that I have read the above statement and that I will not discuss measurements with any previous or potential survey takers until after the completion of this study

#### Descriptive Information

Please place a checkmark next to your answer.

1. Gender

☐ Male

☐ Female

2. Age

☐ < 25

☐ 26-50

☐ >51

3. What is your current level of expertise?

☐ Resident

☐ 1-5 years practicing

☐ >5 years practicing

4. How often do you check cephalometric tracings?

☐ Rarely/Never

☐ Only when unsure of treatment

☐ [Almost] Every patient

5. What system of measurement do you use for space analysis?

☐ Visual approximation

☐ Manual measurement

☐ Computer estimate

For the following pictures of the occlusal view, please estimate the “within arch” space deficiency (crowding) in mm (Keep one decimal e.g 2.0 mm or 3.2 mm). This should be a 2-dimensional measurement of arch length required minus current arch length. This measurement should NOT take into consideration the curve of Spee, curve of Wilson, flare of teeth, etc.

**Case 1**

Maxillary\_\_\_\_\_

Mandibular\_\_\_\_\_

**Case 2**

Maxillary\_\_\_\_\_

Mandibular\_\_\_\_\_

**Case 3**

Maxillary\_\_\_\_\_

Mandibular\_\_\_\_\_



1. Please use your vision to estimate the measurements for the following lateral cephalogram. No other tools allowed.



**1. ANB (Norm = 1.6°)**

- ☐ < -6
- ☐ -6 – <0
- ☐ 0 – 4
- ☐ >4 – 10
- ☐ > 10

**3. L1 – MP (Norm = 95°)**

- ☐ <80
- ☐ 80 – 89
- ☐ 90 – 100
- ☐ 101 – 110
- ☐ >110

**2. U1 – SN (Norm = 102.5°)**

- ☐ < 87
- ☐ 87 – 96
- ☐ 97 – 108
- ☐ 109 – 118
- ☐ >118

**4. Mand Plane to FH/FMA (Norm = 25°)**

- ☐ <13
- ☐ 13 – 20
- ☐ 21 – 29
- ☐ 30 – 37
- ☐ >37

2. Please use your vision to estimate the measurements for the following lateral cephalogram. No other tools allowed.



**5. ANB (Norm = 1.6°)**

- ☐ < -6
- ☐ -6 – <0
- ☐ 0 – 4
- ☐ >4 – 10
- ☐ > 10

**6. U1 – SN (Norm = 102.5°)**

- ☐ < 87
- ☐ 87 – 96
- ☐ 97 – 108
- ☐ 109 – 118
- ☐ >118

**7. L1 – MP (Norm = 95°)**

- ☐ <80
- ☐ 80 – 89
- ☐ 90 – 100
- ☐ 101 – 110
- ☐ >110

**8. Mand Plane to FH/FMA (Norm = 25°)**

- ☐ <13
- ☐ 13 – 20
- ☐ 21 – 29
- ☐ 30 – 37
- ☐ >37

3. Please use your vision to estimate the measurements for the following lateral cephalogram. No other tools allowed.



9. ANB (Norm =  $1.6^\circ$ )

- ☐  $< -6$
- ☐  $-6 - <0$
- ☐  $0 - 4$
- ☐  $>4 - 10$
- ☐  $> 10$

11. L1 – MP (Norm =  $95^\circ$ )

- ☐  $<80$
- ☐  $80 - 89$
- ☐  $90 - 100$
- ☐  $101 - 110$
- ☐  $>110$

10. U1 – SN (Norm =  $102.5^\circ$ )

- ☐  $< 87$
- ☐  $87 - 96$
- ☐  $97 - 108$
- ☐  $109 - 118$
- ☐  $>118$

12. Mand Plane to FH/FMA (Norm =  $25^\circ$ )

- ☐  $<13$
- ☐  $13 - 20$
- ☐  $21 - 29$
- ☐  $30 - 37$
- ☐  $>37$